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ANN MODELLING OF SMALL HOLE DRILLING ON MONEL METAL BY USING ELECTRICAL DISCHARGE MACHINING

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ABSTRACT

The selection of best combination of the process parameters in small hole drilling by Electrical Discharge Machining for an optimum material removal rate with a reduced tool wear rate can reduce machining time and yield better performances. Artificial Neural Network (ANN) has emerged as a powerful tool for modelling complex processes is used for achieving better performance parameter. Artificial Neural Network (ANN) with back propagation algorithm have been used for optimizing and modelling process. The experiments have been designed according to Taguchi L_9 orthogonal array. The input parameters were considered for conducting experimentation are namely Discharge Current, Pulse off time and Pulse on time respectively. The performance measures were Material Removal Rate (MRR) and Tool Wear Rate (TWR). ANN models have been developed with varying number of neurons in the hidden layer from 5 to 10. It was found that one hidden layer with 9 neurons predicted the best results. The predicted values were compared with actual experimental results and the predicted values were almost equal to the expected with very less error.

Keywords

Drilling, Electrical Discharge Machining , Artificial Neural Network and Response Surface Methodology.

Academic Discipline And Sub-Disciplines

Production, Machining and Intrinsic chemistry.

TYPE (METHOD/APPROACH)

Experimental and modelling

INTRODUCTION

Rapid technological advancements, the demands for micro parts in the field of micro electro mechanical system (MEMS), is being increasing [1]. Micro EDM has been identified as one of the powerful micro-machining techniques to machine micro components with obvious advantages of machining complex structures with high aspect ratios, high precision and accuracy irrespective of work-piece material hardness and toughness [2]. Micro-EDM has similar characteristics as EDM except that the size of the tool, discharge energy and axes movement resolutions are in micron level [3]. The application of micro holes found in cooling holes of rotary engine blades for jet engines, holes for ejector pins, core pins, aircraft fasteners, and vent holes for plastic moulds and starter holes for wire EDM operations [4]. In micro-EDM, many factors that affect the process performance these factors can be related either to the process parameters (such as voltage, peak current, pulse duration, spark gap and flushing conditions) or to the system (such as type of dielectric fluid, tool properties, chemical and physical material properties) [5]. Any small change in the process parameters may affect the performance of the process and quality of the micro hole which leads increased cost and waste of time. Due to the high industrial competitiveness, the prime need for manufacturing companies are to produce high quality products at the lower possible cost. Hence selection of suitable process parameter is very important in micro EDM since it has been carried out by conservative data provided by the manufacturers of EDM machine or by operator's experience. Shajan et al [6] formulated the mathematical model by using multiple regression analysis to report the relationship between input and output process variables. Sarkar et al [7] successfully developed a second order mathematical model by using response surface methodology in terms of machining parameters for surface roughness and cutting speed in wire EDM process. It was proved that surface quality of the workpiece decreased due higher cutting speed. Another study carried out to develop the mathematical model by using regression analysis in order to analyse the relationship between surface roughness and electrical input process parameters in wire EDM process is done by Esme et al [8]. It yields that increasing the pulse duration had resulted in better surface roughness of the workpiece during machining process. Sushant Dhar et al [9] formulated a second order non linear mathematical model to study the effect of current, pulse on time and gap voltage on material removal rate, tool wear rate and radial over cut on electrical discharge machining of Al- 4Cu- 6Si alloy with 10Wt percentage of SiCp Composites. Rao et al [10] developed the mathematical model for predicting the material removal rate, tool wear rate and Surface roughness. Erzurumlu and Oktem [11] compared an empirical model with an ANN model in determining the surface quality of moulded parts. They concluded that the ANN model led to slightly accurate surface roughness predictions. Dutta and Pratihar [12] performed modelling of the Tungsten Inert Gas (TIG) welding process using regression and neural models. The neural model was proved to be more adaptive compared to the linear regression analysis. Tsao and Hocheng [13] have used a L_{27} orthogonal array for conducting the experiments in the drilling process. They developed a neural and regression model by using the experimental data. They concluded that the radial basis function neural model is more effective than the regression model for the evaluation of drilling-induced thrust force and surface roughness in the drilling of composite material. Saha et al [14] had developed an ANN model and a regression model to predict the cutting speed and surface roughness of the WEDM process. Their results showed that the neural model is better than the regression model in exploiting the randomness of the material removal process of WEDM, due to the formation of several normal and abnormal sparks. Therefore, in this research, regression and neural network techniques were employed for the modelling of the highly stochastic Micro-EDM process and the prediction capabilities of both the models were evaluated. There have been many previous attempts leading to the improvement of process efficiency by controlling the process parameters. Hence proper selection of process parameters still remains a challenge and machining of monel metal has not been addressed. In the present work the Multiple regression analysis is used for model the experiments and artificial neural network (ANN), Fuzzy logic has been used for process optimization.

2.0 MATERIAL & METHODS

Monel 400 alloy is considered as a most promising and commonly used nickel based alloys due to their excellent corrosion resistance and toughness over a wide temperature range. Monel has been widely used in chemical industries, food processing industries, heat exchanger tubing, nuclear reactors, sub marine and ship propellers etc [15] Monel alloys work hardens rapidly as it undergoes high strains during machining. This hardening effect slows further machining. Therefore, it is very difficult to machine these alloys using conventional machine tools [16]. The process parameters, selected for the present investigation, are Discharge Current, Pulse on time and Pulse off time since the significant influence is on the EDM process performances [17-19]. Their influence on the Material Removal Rate and Tool wear rate are tested through the set of the planned experiments based on L_9 orthogonal array of Taguchi's design of experiments. Table.1 shows the factors and their levels in coded and actual values. Commercially obtained Monel 400 alloy having thickness of 5mm were used as a workpiece material. The chemical composition (weight %) of Monel 400 alloys is as follows: C: 0.047, Si: 0.172, Mn: 1.03, P: 0.012, S: 0.01, Cr: 0.1, Mo: 0.1, Fe: 1.66, V: 0.029, W: 0.1, Cu: 29.24, Al: 0.01, Co: 0.103, Nb: 0.1, Ti: 0.047, Mg: 0.031, and Ni: 67.4. Brass electrode (Cu-61.8%, Zn-37.2% and impurities-1.0%) of diameter 2.0mm was selected to drill holes in the workpiece. Commercial grade kerosene was used as the dielectric fluid and side injection of the dielectric fluid was opted.

Table- 1 Process Parameters and their levels

PARAMETERS	FACTORS	LEVELS		
		1	2	3
Pulse off time (μs)	A	2	3	4
Discharge current (A)	B	4	5	6
Pulse on time (μs)	C	4	5	6

2.1 PLAN OF EXPERIMENT:

Taguchi's technique has been widely used in DOE, and it is employed to perform the experimental design [20]. Taguchi has standardized methods for each of these DoE application steps. This approach in finding factors that affect a product in a DoE can dramatically reduce the number of trails required to gather necessary data. Thus, DOE using Taguchi approach has become a much more attractive tool to practicing engineers and scientists. The aim of conducting an orthogonal experiment is to find the optimum level for each factor and to ascertain the relative importance of the individual factors in terms of their main effects on the response. The experimental results are summarised in table 2. The Figure 1 shows the Monel Alloy which is drilled by EDM.

Table: 2 Experimental Results

Trial Nos	A	B	C	Material removal rate	Tool wear rate
1	1	1	1	0.00353	0.01972
2	1	2	2	0.00909	0.05390
3	1	3	3	0.01010	0.07985
4	2	1	2	0.00308	0.02246
5	2	2	3	0.00446	0.03022
6	2	3	1	0.00688	0.05934
7	3	1	3	0.00273	0.02156
8	3	2	1	0.00395	0.03404
9	3	3	2	0.00876	0.05934

3.0 RESPONSE SURFACE METHODOLOGY:

Response surface methodology (RSM) is a collection of mathematical and statistical techniques that are useful for modelling and analysis of various process parameters and responses in order to determine the relationship between input parameters and outcome responses and the objective is to optimize the responses [21]. It is a sequential experimentation strategy for building and optimizing the empirical model. For the present investigation, RSM has been used for developing the mathematical models in the form of multiple regression equations for the quality characteristic of machined parts produced by Micro EDM process. A second order polynomial regression equation was used as the mathematical expression [22] to correlate the process parameters and the performance characteristics of the micro EDM process and it is stated as follows:

$$Y= b_0+b_1Toff+b_2I+b_3Ton+b_{11}Toff^2+b_{22}I^2+b_{33}Ton^2+ b_{12}ToffI+ b_{13}\,Toff\,Ton+b_{23}\,I\,Ton$$

where b_0 is the constant, b_1, b_2, b_3,.....b_{15} are the coefficients that depend on respective main and interaction factors and Y is the response parameter.

MRR= -0.000960 - 0.007173 A + 0.005288 B + 0.007223 C + 0.001553 A*A - 0.000248 B*B - 0.002027 C*C - 0.000650 A*B + 0.000523 A*C

TWR= -0.01213 - 0.01796 A + 0.02089 B + 0.03466 C + 0.007395 A*A + 0.004583 B*B - 0.008698 C*C - 0.008507 A*B - 0.000517 A*C

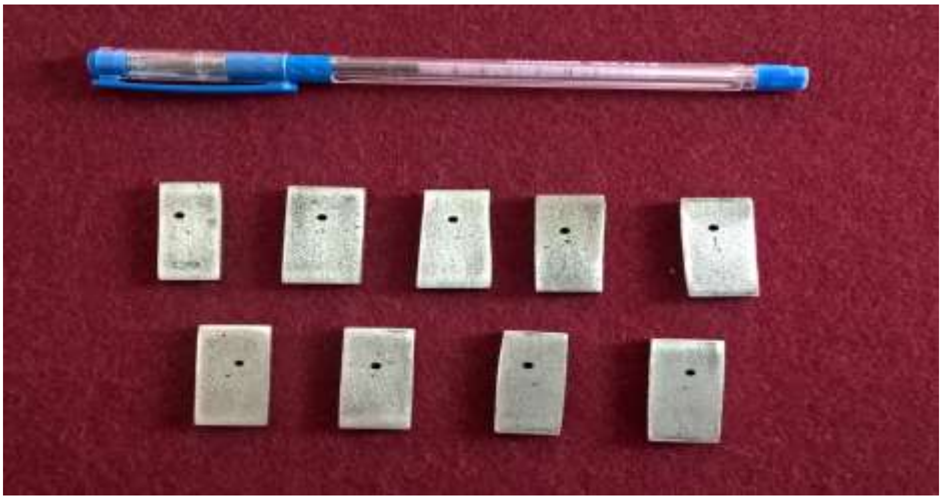

Fig:1 EDM Drilled Monel Alloy.

4.0 ANN MODELLING:

ANN is a computational method which can be applied to solve any linear and non linear problems in engineering. Micro-EDM drilling is a highly complex and stochastic to model analytically by understanding the physics of the process. Hence, many researchers have been used different modelling techniques to predict the behaviour of the process. The developed ANN model architecture for predicting the machining performance of Micro EDM is shown in Figure 2. Here, Pulse on time, Pulse Off time and Discharge current are considered as input. Material removal rate and tool wear rate are considered as output. Approximately 65% of the experimental data (5 values) were used for training, while the remaining 35% (4values) were reserved for testing. A single-layer perception network was used for nonlinear mapping between the input and output data. The Back Propagation algorithm was used for training the ANN model. This algorithm uses the supervised training technique, where the network weights and biases are initialised randomly at the beginning of the training phase. The error minimisation process is achieved using the gradient descent rule. The sigmoid and linear functions were chosen as the activation functions for hidden and output layers. The developed ANN was trained and tested by means of MATLAB 7.2 (MathWorks, Natick, MA).

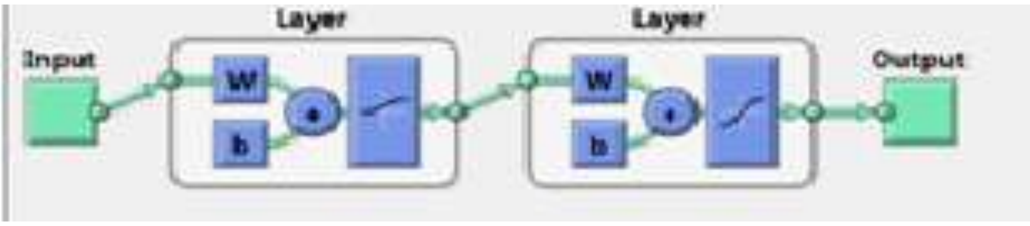

Fig: 2 Network topology of Developed ANN Model

The different numbers of neurons in hidden layers are used to develop the ANN model for selecting the best network. Correlation coefficient between desired target and actual output of training, validation and testing is shown in Fig. 3. In this study the neurons of hidden layer varied from 6 to 11. Figure 4 indicates the variation in percentage error. It is evident from the graph that 7 neurons give the best prediction results with low percentage of error. To measure the effectiveness of the developed ANN model, the experimental values are compared with the predicted value and shown in figure 5 and 6. In ANN the predicted average percentage of error for MRR is 8.75% and TWR is 10.11%

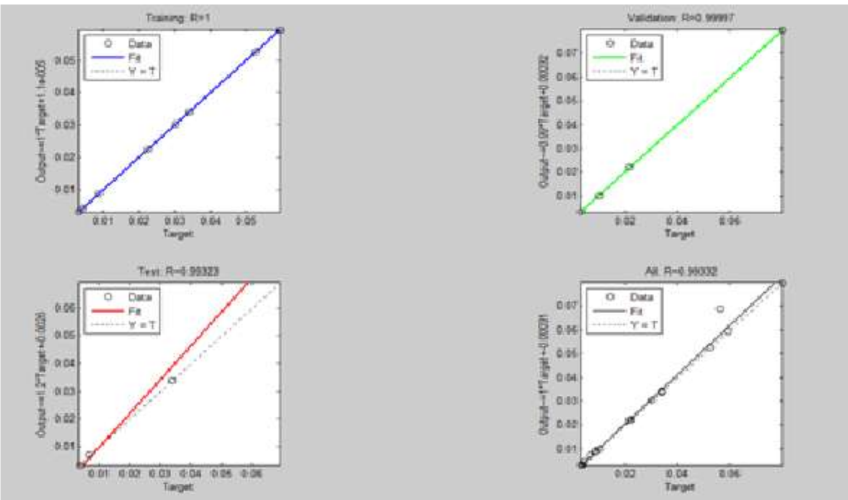

Fig: 3 Correlation Coefficients

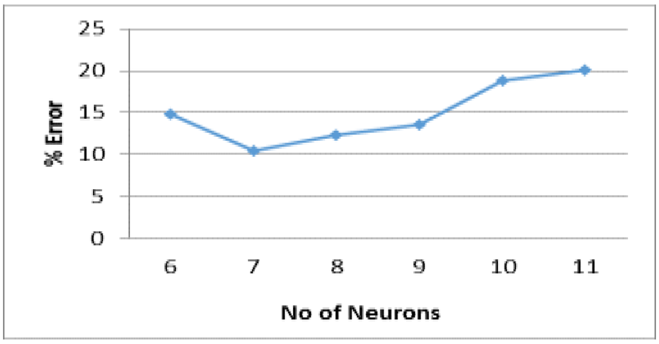

Fig: 4 Variation in Percentage Error

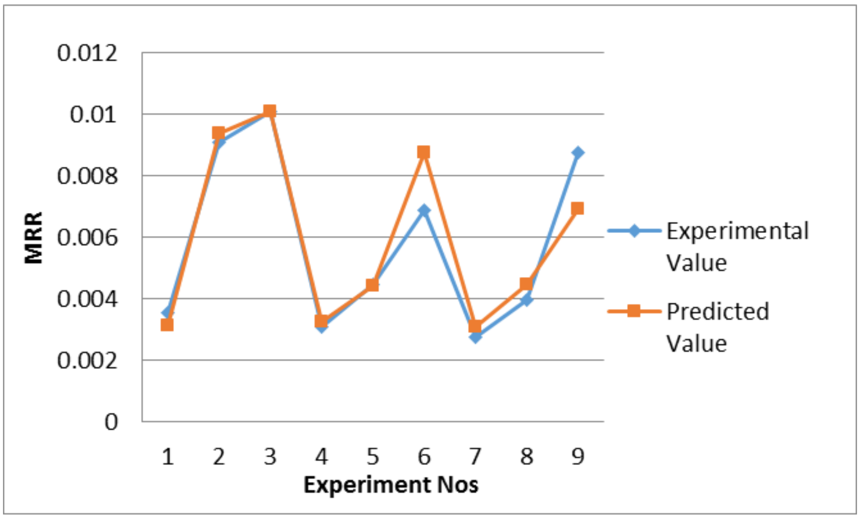

Fig: 5 Variation of MRR and MRR output of ANN

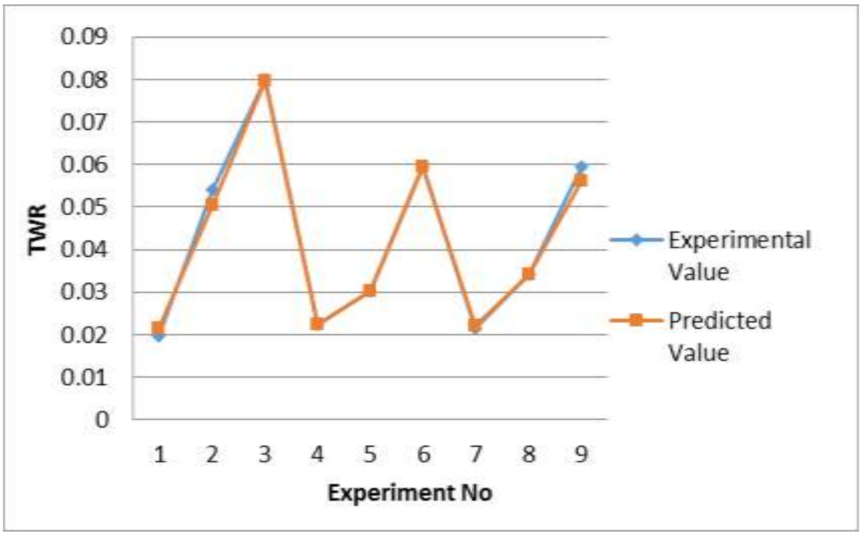

Fig: 6 Variation of TWR and TWR output of ANN

5.0 CONCLUSIONS:

The impact of process parameters and the optimum process parameters for EDM small hole drilling process are systematically investigated by Taguchi and Artificial Neural Network. The following conclusions have been arrived at,

(i) Approach of Taguchi and Artificial Neural Network is an efficient productive method which is able to reduce the cost and time of experiments and to utilize the data obtained to the maximum extend. This methodology is not only time saving and cost effective but also efficient and precise in determining the machining parameters. It is found that current has a significant influence on the total machining time.

(ii) The developed ANN model is highly effective for predicting the process performance. The predicted and experimental values are highly correlated with correlation coefficient of 0.97– 0.99. Comparison of the ANN predictions and the experimental results demonstrated. It is clear that the developed ANN model is useful to test the operating conditions of the process with the use of limited number of experiments and is also useful for manufacturers and application engineers for predicting the operating conditions of the process under different levels of input parameters.

(iii) The best performance characteristics are obtained with discharge current of 6 A, Pulse on time of 6µs and pulse off time of 2 µs.

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Author' biography with Photo

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